Day 2

Designing Cooking Stoves that Cook Faster, Are More effective, Use Less Wood and Make Less Smoke

Day 2 – Designing Stoves

- Today we will learn about designing stoves: *"What is an improved Stove?" and "How do I know, and how can I prove, that my stove is improved?"*
  - Improving Heat Transfer and Combustion Efficiency
  - 10 Design Principles
  - Show performance of existing stoves through testing, as published in Comparing Cooking Stoves
  - Discuss benchmarks that define an "improved stove"

How is a stove improved?

Basic stove thermodynamics:

Heat Transfer Efficiency		Fuel Use
+ Combustion Efficiency	⟷	+ Emissions
= Overall Efficiency		= Overall Performance

Heat Transfer Efficiency

In continuous feed stoves, Heat Transfer Efficiency (HTE) into the pot is determined by:

- *Temperature* difference between the flue gases and the outer surface of the pot
- *Proximity* of the flue gases passing by the pot
- *Velocity* of the flue gases reduces the boundary layer
- Conductivity of Pot
- Surface Area of Pot exposed to hot gases

Increasing HTE decreases fuel use.

Combustion Efficiency

Combustion Efficiency (CE) is determined by:

- *Temperature* of the combustion area should be as hot as possible to burn up pollution.
- *Incoming air* should be warmed and directed into the fire and coals.
- *Amount of fuel* should be appropriate. Too much fuel creates too much gas for the flame and emissions rise.
- *The Shape of the combustion chamber* should encourage mixing of gases, air, and flame. This is the most important factor in clean combustion.

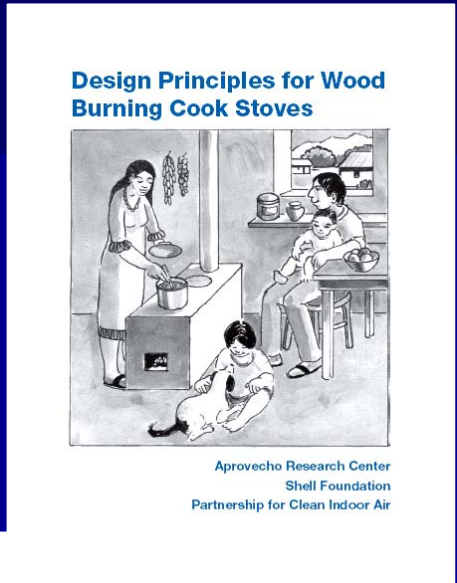
Increasing CE decreases harmful emissions.

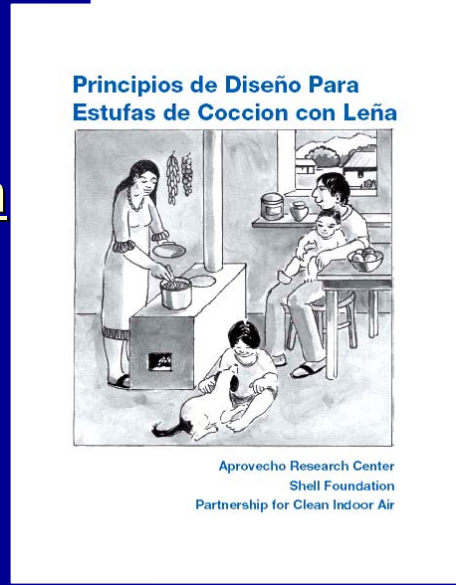
Combustion Efficiency

- Mixing, Moisture, Metering
- Time, Temperature, Turbulence
- Top Air/Bottom Air: Gasification Continuum

Optimizing HTE and CE = Design Principles

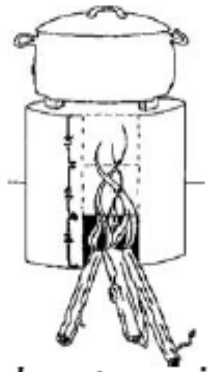
- Guidelines for optimizing both HTE and CE are provided in the "*10 Design Principles for Wood Burning Cook Stoves*" developed by Dr. Larry Winiarski.
- Some copies available here today, can also be downloaded from PCIA: http://www.pciaonline.org/resources.cfm
- Following all 10 principles frequently results in a "rocket" stove





Ten Design Principles For Wood Burning Stoves

Aprovecho Research Center
Advanced Studies in Appropriate Technology



By Dr. Larry Winiarski

1. ***Insulate around the fire*** *using lightweight, heat-resistant materials.*
2. *Place an insulated short* ***chimney right above the fire*** *to burn up the smoke and speed up the draft.*
3. *Heat and burn the* ***tips of the sticks*** *as they enter the fire to make flame, not smoke.*
4. *High and low heat are created by* ***how many sticks*** *are pushed into the fire.*

5. *Maintain a **good fast draft from under the fire**, up through the coals. Avoid allowing too much extra air in above the fire to cool it.*

6. ***Too little draft** being pulled into the fire **will result in smoke and excess charcoal**.*

7. ***Keep unrestricted airflow** by maintaining constant cross sectional area through the stove. The opening into the fire, the size of the spaces within the stove through which hot air flows, and the chimney should all be about the same size.*

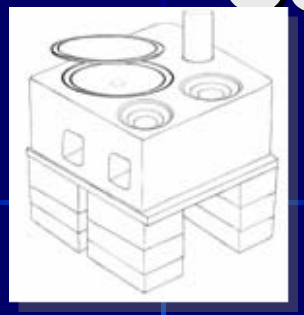
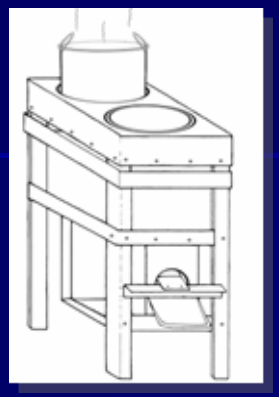
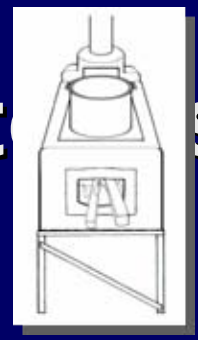
8. *Use a **grate** under the fire.*

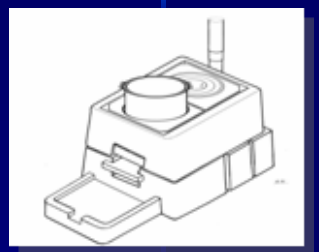
9. ***Insulate the heat flow path**, from the fire, to and around the pot(s) or griddle.*

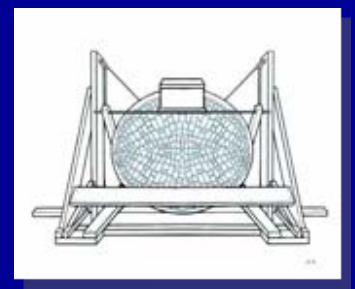
10. *Maximize heat transfer to the pot with **properly sized gaps**.*

Comparing Cooking St s

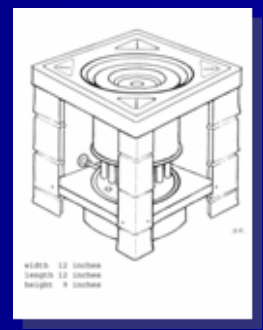
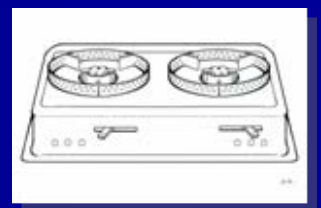
Results of three tests each of over 40 stoves helped to create the stove performance library…

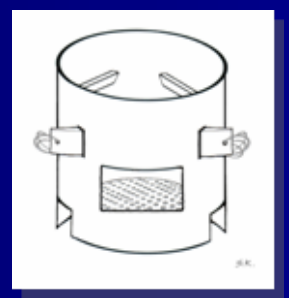


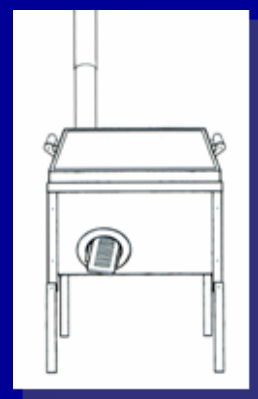




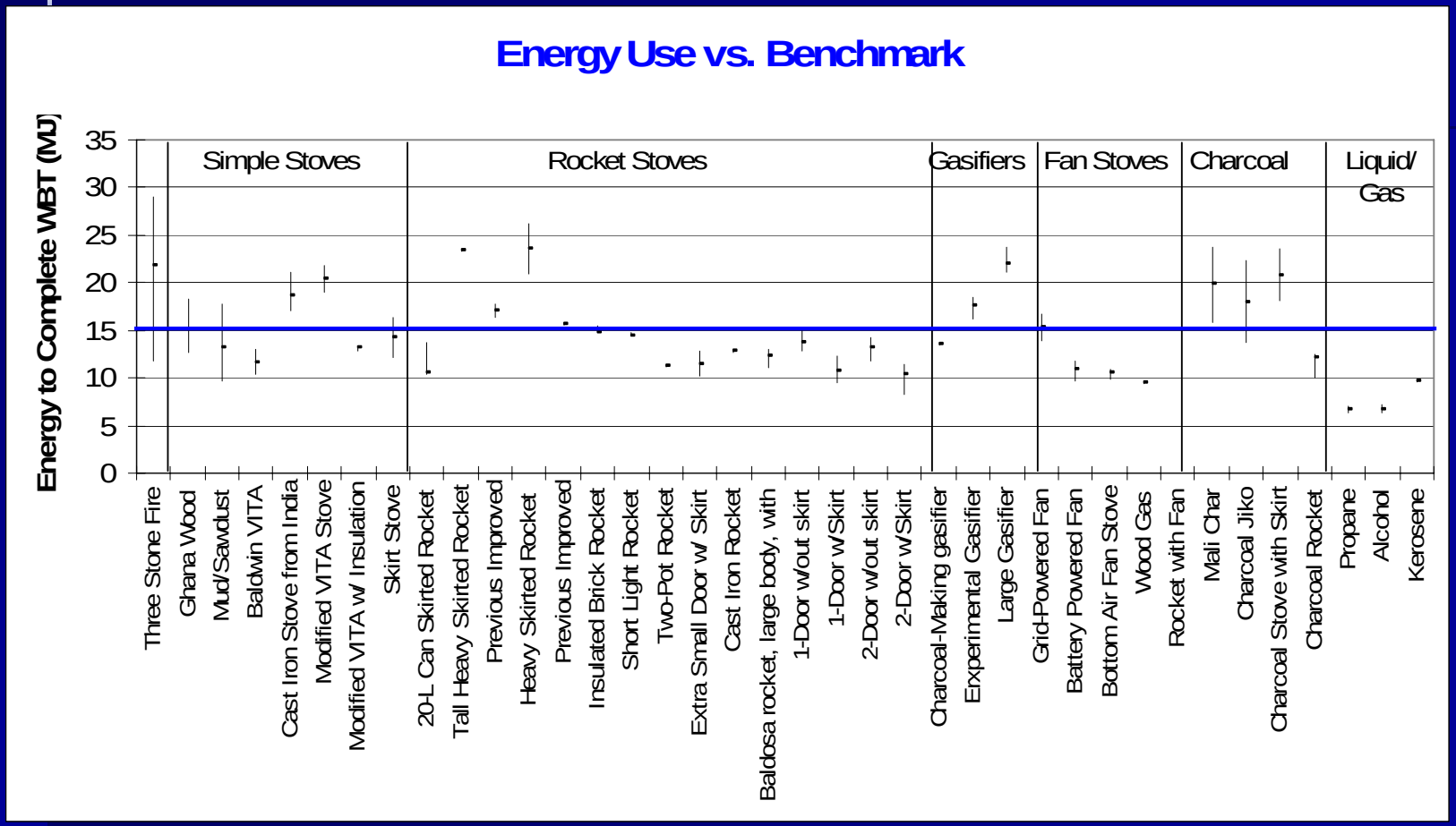






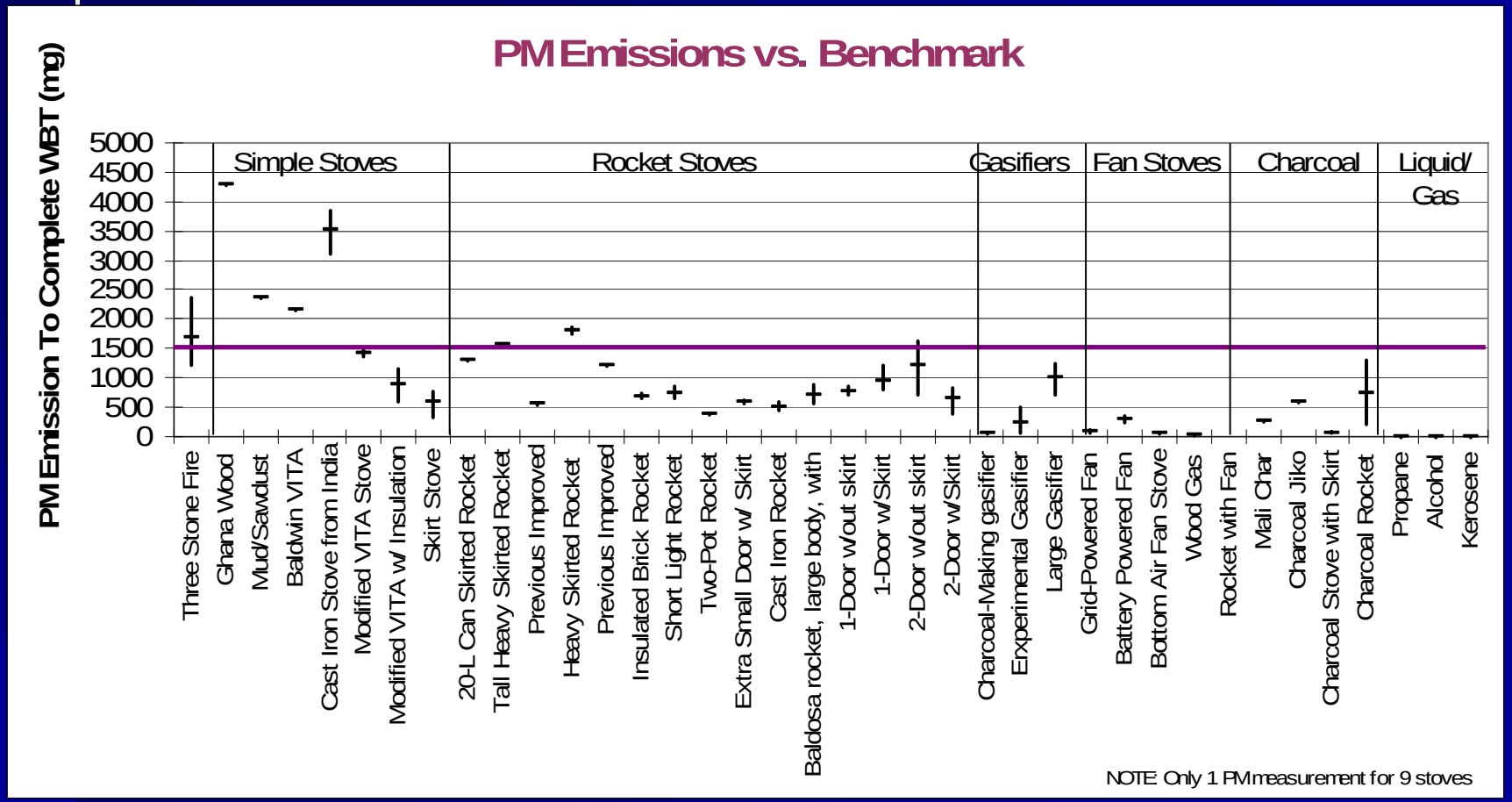
Fuel Use Benchmark

A cooking stove should use less than 15,000 kJ of energy or 850 grams of testing wood to complete the WBT.



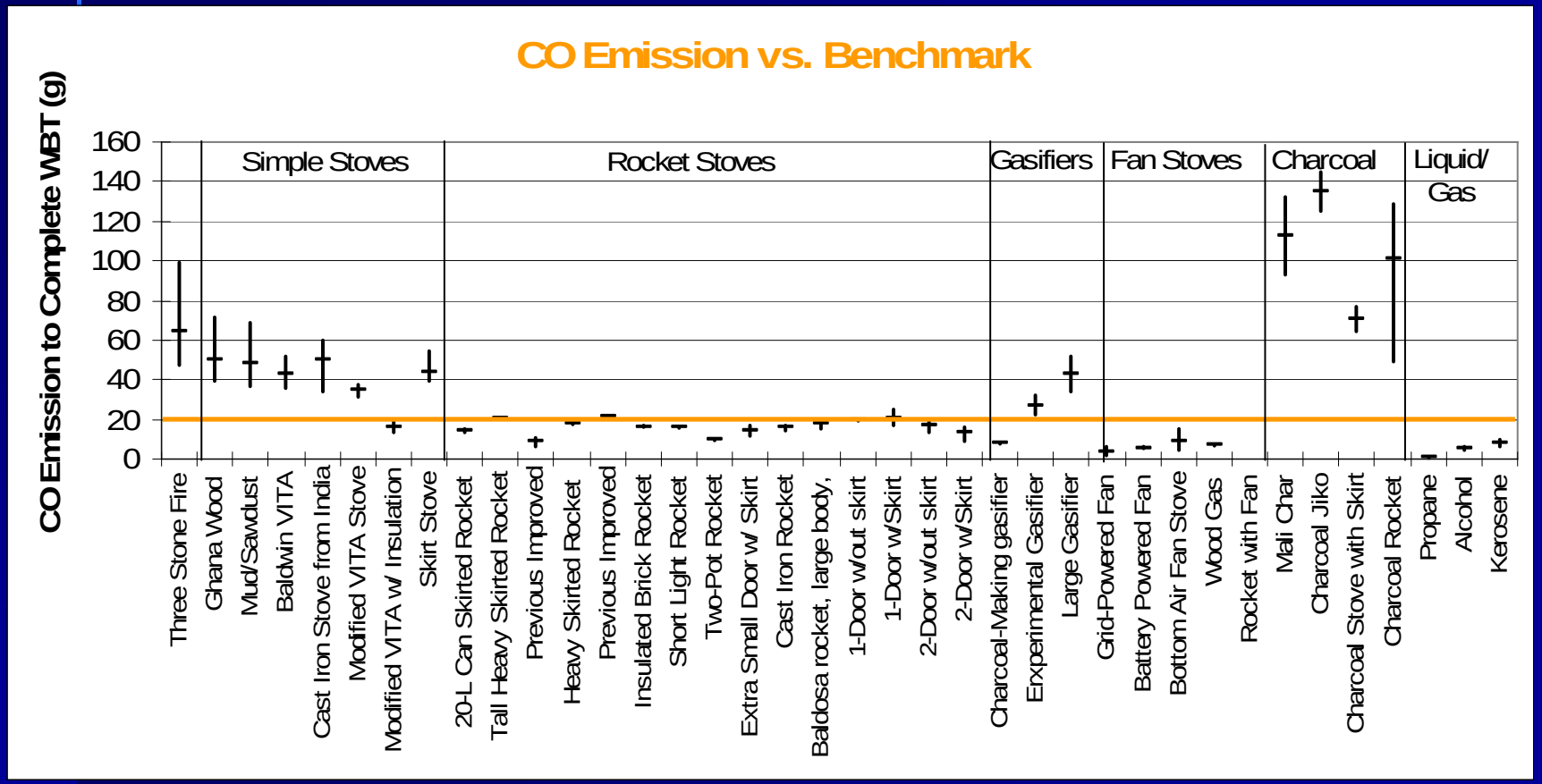
Particulate Matter Benchmark

A cooking stove should emit less than 1500 milligrams of Particulate Matter to complete the WBT.



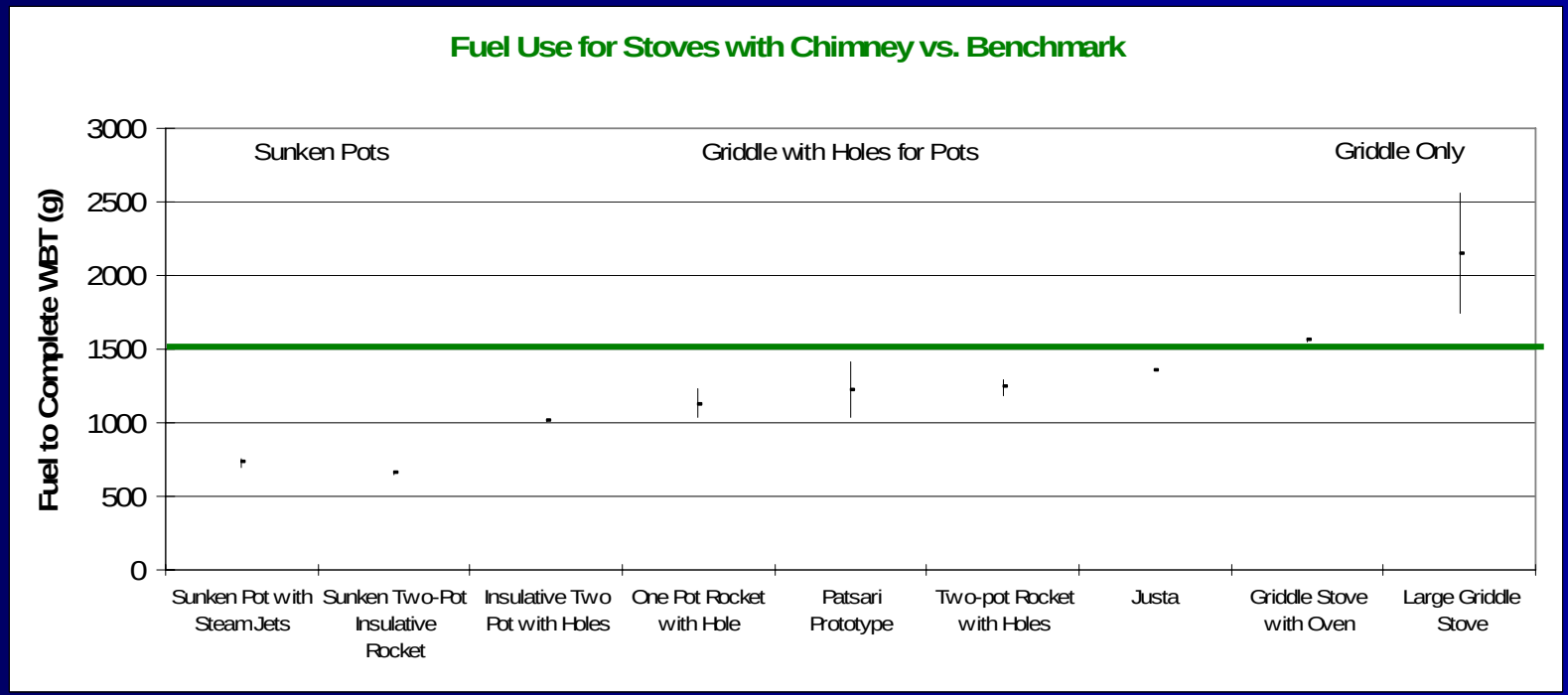
Carbon Monoxide Benchmark

A cooking stove should emit less than 20 grams of Carbon Monoxide to complete the WBT.



Chimney Stove Benchmark

A cooking stove with chimney is exempt from the previous standards provided it does not leak. A stove with functioning chimney should use less than 30 MJ of energy or 1500 grams of testing wood to complete the WBT.



A stove with chimney is checked for leaks by placing a HOBO-type CO meter 30 cm above the stove.

If less than an average of 50 ppm CO is emitted, the stove is exempt from non-chimney standards

Current Shell Foundation Benchmarks

1.) **Fuel use**: Using the International Testing Pot a cooking stove without a chimney should use **less than 15 MJ of energy** or 850 grams of testing wood to bring to boil* 5 liters of water and then simmer it for 45 minutes during the UCB Water Boiling Test**.

2.) **Emissions**: The cooking stove without a chimney should produce **less than 20 grams of Carbon Monoxide** to boil 5 liters of water and then simmer it for 45 minutes during the UCB Water Boiling Test.

3.) **Emissions:** The cooking stove without a chimney should produce **less than 1500 milligrams of Particulate Matter** (2.5 microns or smaller) to boil 5 liters of water and then simmer it for 45 minutes during the UCB Water Boiling Test.

4.) **Chimney Stoves Emissions Exemption:** Wood burning stoves with chimneys are exempt from the above standards if the stove does not allow more than **50 parts per million** of Carbon Monoxide to pollute the air 30 cm above the stove. Exempt stoves with Chimneys should use **less than 30 MJ of energy** or 1500 grams of testing wood to boil 5 liters of water and then simmer it for 45 minutes during the UCB Water Boiling Test.

*Boiling data is the average of cold and hot start phases of the WBT and corrected for starting temperature.
**The WBT is being revised to allow for smaller water quantity for low-powered stoves.
Three tests of the stove are used to determine performance with statistical confidence.

Limitations of Benchmarks

- There are more aspects to a stove than the benchmark results. To be successful, a stove project must also consider:
  - User-Friendliness
  - Cultural appropriateness
  - Fuel availability, preparation requirements
  - Safety
  - Affordability of stove and fuel
  - And more...
- A stove that is not used will not be effective – therefore it is crucial to include local women when creating an appropriate stove design.

Overview of Improved Biomass Stoves

- Rocket Stoves improve heat transfer and combustion efficiency.
  - PRO - cleaner burning than traditional stoves, less fuel needed to cook, minimal fuel preparation required, traditional method of tending fire, inexpensive.
  - CON - not as clean burning as gasifiers and fan stoves
- Gasifiers restrict primary air to the fire, which evaporates the wood gas and then burns it, leaving charcoal.
  - PRO – Clean burning, no tending required, inexpensive
  - CON – Prepared fuel in small pieces is needed, no control over burning rate or amount of time the batch will last
- Fan Stoves use a small electric fan to force air into the fire.
  - PRO – Extremely clean burning and fuel efficient due to high velocity and excellent mixing
  - CON – Prepared fuel and electricity (grid, battery, or thermoelectric) required, difficult to design, cultural considerations
- Stoves with chimney help to eliminate IAP.
  - PRO – Smoke removed from kitchen, pots may stay cleaner, can be multi-purpose
  - CON – Frequently use more fuel if a griddle is needed, smoke is still emitted into neighborhood, generally larger and more expensive, chimney must be installed and maintained